

# What is the uncertainty in MODIS aerosol optical depth in the vicinity of clouds ?



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## Introduction

- MODIS dark-target (DT) algorithm retrieves aerosol optical depth (AOD) using a Look Up Table (LUT) approach
- Global comparison of AOD (Collection 6) with ground-based sun photometer gives an Estimated Error (EE) of  $\pm(0.04 + 10\%)$  over ocean. However, EE does not represent per-retrieval uncertainty
- For retrievals that are biased high compared to AERONET, here we aim to closely examine the contribution of biases due to presence of clouds and per-pixel retrieval uncertainty

## Approach

- We calculate the per-pixel retrieval uncertainty from
  - Atmospheric correction
  - Variability in reflectance in 10 km retrieval area
  - Aerosol model assumption
  - Surface albedo
  - Cloud contamination or enhanced radiation in vicinity of clouds
- Our aim is to quantify the uncertainty in retrieved AOD due to as many different sources as we can and identify the relatively dominant source of uncertainty in AOD retrieval

## Per-Pixel Retrieval Uncertainty

Comparing AOD Uncertainty

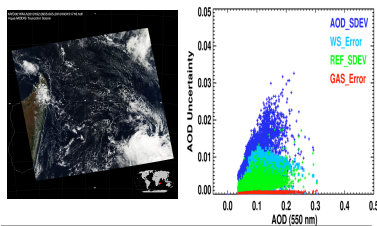


Figure 1 Using Jacobian approach to estimate each of four sources of uncertainty for all retrieved pixels in the example MODIS granule shown at left.

From the above results we find that,

- Uncertainty is a function of retrieved AOD.
- Uncertainty from error in ancillary data / gas absorption correction is lowest here
- Uncertainty from surface albedo approximation is nearly double that from standard deviation of reflectance within 10 km retrieval region
- Largest uncertainty in over Ocean AOD retrieval comes from the multiple solutions that yield an acceptable retrieval (See Fig 1)

## References

- Levy, R. C., Mattoo, S., Munchak, L. A., Remer, L. A., Sayer, A. M., Patadia, F., and Hsu, N. C.: The Collection 6 MODIS aerosol products over land and ocean, Atmos. Meas. Tech., 6, 2989-3034, doi: 10.5194/amt-6-2989-2013, 2013.
- Cox, C., and W. Munk, Slopes of the sea surface deduced from the photographs of sun glitter, Bull.Suipinst.Oceanogr., 6, 401 – 488, 1956
- P. Koepke, "Effective reflectance of oceanic whitecaps," Appl. Opt. 23, 1816-1824 (1984).

## Questions?

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## Validating Per-pixel Retrieval Uncertainty

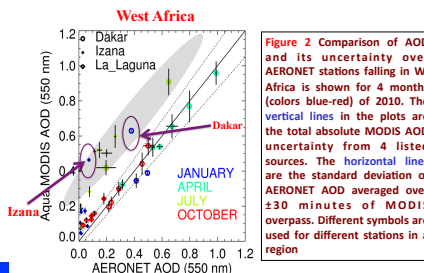
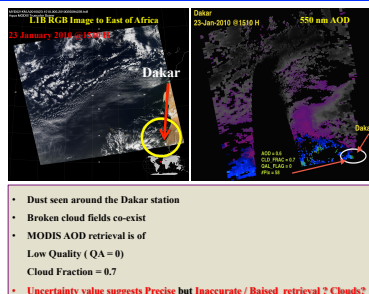


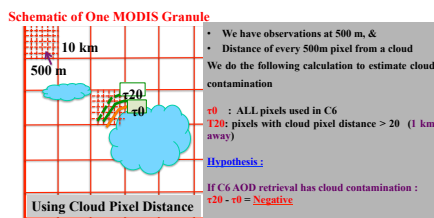
Figure 2 Comparison of AOD and its uncertainty over AERONET stations falling in W. Africa is shown for 4 months (colors blue-red) of 2010. The vertical lines in the plots are the total absolute MODIS AOD uncertainty from 4 listed sources. The horizontal lines are the standard deviation of AERONET AOD averaged over  $\pm 30$  minutes of MODIS overpass. Different symbols are used for different stations in a region

- When compared to ground-based AERONET sun-photometers, clearly the performance of the algorithm is different over different regions and seasons
- For most data-points within the EE envelope (dashed lines), the uncertainty is within EE of retrievals over ocean
- For retrievals with high uncertainty, the AERONET AOD standard deviation is also large in many cases and there are exceptions to this too
- For outliers, the per-pixel uncertainty is no necessarily large – lets take a close look at an outlier below

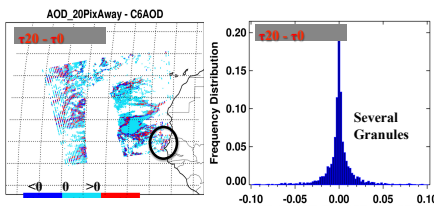
## Cloud Contamination Issue



## Exercise 1 : What can we learn about cloud contamination from our retrievals ?

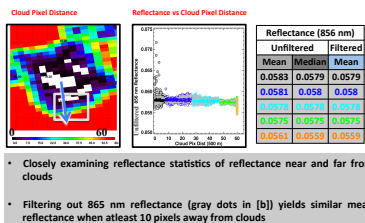
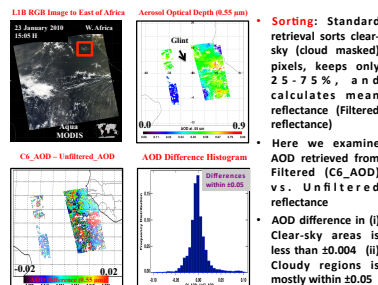


## Exercise 1 : Results

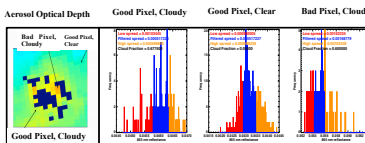


- Notice blues and reds in spatial distribution of AOD difference [Figure 3 (a)] : there is low and high bias around cloudy regions
- AOD Difference Histogram [Figure 3 (b)] shows
  - Gaussian shape
  - $\Delta\tau \approx \pm 0.05$
  - Most differences within  $\pm 0.03$
- => Reasonable overall cloud screening
- Low Quality flags => Clouds contamination

## Exercise 2 : Investigating Reflectance "Sorting" in Clear and Cloudy Areas



- Closely examining reflectance statistics of reflectance near and far from clouds
- Filtering out 856 nm reflectance (gray dots in [b]) yields similar mean reflectance when atleast 10 pixels away from clouds



- Looking at histograms of few pixels with good and bad AOD retrievals, shows that
- Reflectance histogram of Clear-sky pixels is gaussian → same means in table above
- Reflectance histogram of Cloudy pixels is skewed → filter cut-off will govern high / low bias in AOD

## Conclusions

- We have characterized AOD uncertainty at 550 nm, due to standard deviation of reflectance in 10 km retrieval region, uncertainty related to gas ( $H_2O$ ,  $O_3$ ) absorption, surface albedo, and aerosol models
- The uncertainty in retrieved AOD seems to lie within the estimated over ocean error envelope of  $\pm(0.03+10\%)$
- Regions between broken clouds tend to have higher uncertainty
- Compared to C6 AOD, a retrieval omitting observations in the vicinity of clouds ( $\leq 1$  km) is biased by about  $\pm 0.05$
- For homogeneous aerosol distribution, clear-sky retrievals show near zero bias
- Close look at per-pixel reflectance histograms suggests retrieval possibility using median reflectance values

## Future Work

- Develop statistics and perform a global land - ocean evaluation of as many uncertainty sources as we can
- Further Investigate uncertainty due to biases from cloud, snow contamination